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December 8, 1831.

HIS ROYAL HIGHNESS THE DUKE OF SUSSEX, K.G., President, in the Chair.

Thomas Maclear, Esq., Philip Hardwick, Esq., the Right Hon. Lord Oxmantown, and Henry Robinson Palmer, Esq., were elected Fellows of the Society.

The reading of a paper, entitled "Experimental Researches in Electricity," by Michael Faraday, Esq. F.R.S. was commenced.

December 15, 1831.

JOHN WILLIAM LUBBOCK, Esq. M.A., V.P. and Treasurer, in the Chair.

The reading of Mr. Faraday's paper, entitled "Experimental Researches in Electricity," was concluded.

This paper is divided into four parts: the first being on the Induction of Electric Currents; the second, on the Evolution of Electricity from Magnetism; the third, on a new Electrical Condition of Matter; and the fourth, on Arago's Magnetic Phænomena.

The author defines *electrical induction* to be the power which electrical currents possess of *inducing* any particular state upon matter in their immediate neighbourhood. A great length of copper wire, 1-20th of an inch in diameter, was wound round a cylinder of wood so as to compose two helices, the coils of which were intermixed, but prevented from touching each other by interposed threads of twine and calico. One helix was connected with a voltaic battery, and the other with a galvanometer. No effect was perceived on the latter, with a battery of 10 plates: a slight effect only with one of 100 plates; and a distinct deflection of the needle of the galvanometer occurred when the contact was made with a battery of 120 plates. While the contact was preserved, the needle returned to its natural position, and was unaffected by the electric current passing through the wire connected with the battery; but on breaking the connexion, the needle of the galvanometer was again deflected, but in a direction contrary to that of its former deflection. Hence it is inferred that the electric current sent by the battery through one wire, induced a similar current through the other wire, but only at the moment the contact was made; and a current in the contrary direction when the passage of the electricity was suddenly interrupted. These transitory currents, resembling waves, were found to be capable of magnetizing needles placed within the helix. Collateral currents, either in the same or in opposite directions, exert no permanent inductive power on each other.

No other evidence of the electric action of these induced currents could be detected, such as the appearance of a spark, the ignition of fine wires, or of charcoal, impressions on the tongue, contractions in the muscles of frogs, or chemical decompositions. Yet these induced currents were found to be capable of passing through fluids, when interposed to a small extent in the circuit.

Similar effects were apparently produced by the inductive influence of ordinary electricity directed through the first set of wires.

The second part of this paper contains the account of experiments in which the helix connected with the voltaic battery was wound round one side of an iron ring, welded from soft round bar-iron; while another helix connected with a galvanometer was coiled round the opposite side of the ring. The electrical indications obtained by this apparatus were much more considerable than in the former case, but were equally transitory, and were of opposite kinds on the interruption of the contacts with the battery. By interposing charcoal points in the circuit of the induced helix, a minute spark was perceived whenever the contacts were made or broken off; but no ignition of wires or other electric effects could be obtained. Electric currents were also induced in a helix into which a soft iron cylinder was introduced, whenever that iron was rendered magnetical by induction from magnets applied to its ends. The sudden introduction or removal of a magnet, in the place of the iron cylinder, produced similar effects on the helix.

In many of these experiments the author employed the large compound magnet constructed by Dr. Gowin Knight, and belonging to the Royal Society. Similar effects were produced when the iron was surrounded by a piece of copper plate wrapped once round it with its edges connected with the wires of the galvanometer. Currents were induced on a wire coiled into a flat spiral, by bringing one of the poles of the powerful magnet of Dr. Knight opposite to its centre. Even single wires brought near the pole of this magnet had electric currents induced in them. But all attempts to obtain chemical effects by these currents of electricity induced by magnetism were unsuccessful.

In the third part of the paper the author regards the condition in which a conducting wire exists while it is subject either to volta-electric, or magneto-electric induction, as a peculiar one, which he designates by the term *Electro-tonic state*. This peculiar condition shows no electrical effects while it continues, nor does it exert any sensible action on matter, or on other electrical currents, either of an attractive or repulsive kind; nor does it tend either to accelerate or to retard those currents.

In the fourth part of the paper the author relates a great number of experiments, which concur in proving that when a piece of metal is moved in any particular direction, either in front of a single magnetic pole, or between the opposite poles of a horse-shoe magnet, electrical currents are developed which pass along the substance of the metal in a direction transverse to that of its own motion. By the application of this principle, the author is enabled to explain the various phænomena which take place in the experiments of Arago and others, where magnetic action appears to be developed by rotation; and which have been erroneously attributed to simple magnetic induction, and to the time supposed to be required for the progress of that induction. The electro-magnetic effect of the electric current induced in a conductor by a magnetic pole, in consequence of their relative motion, is such as tends continually to diminish that relative motion; that is, to bring the moving bodies into the state of relative rest; so that if the one be made to revolve by an extraneous force, the other will tend to revolve with it in the same direction, and with the same velocity.

A paper was read, entitled "Some Remarks on the internal Structure of the Platypus Anatinus (*Ornithorhynchus paradoxus*, Blum.)." By Richard Griffin, Esq. Communicated by Dawson Turner, Esq. F.R.S.

Having an opportunity of examining two specimens of the Ornithorhynchus, the one male, the other female, belonging to the Norfolk and Norwich Museum, the author found in the latter two large mammary glands, one on each side of the chest, and covering nearly the whole under surface of the animal; numerous ducts proceeded from them, perforating the skin, at two circular portions, which presented no elevation corresponding to nipples. The Fallopian tubes terminate by very small orifices in the cloaca: posterior to their terminations the author observed two slightly projecting processes, containing each the orifice of a duct which proceeds to a length of at least two inches, but the continuation of which could not be traced in the specimen examined in consequence of the injuries it had received. In the male, three pointed processes were noticed at each extremity of the corpora cavernosa of the penis, the cavities of which do not communicate with one another, and are separated before their termination. The spur of the male is furnished with a sac, of the size of a pea, containing a poisonous fluid, which by means of a canal is conducted into a wound inflicted by the spur.

December 22, 1831.

HIS ROYAL HIGHNESS THE DUKE OF SUSSEX, K.G., President, in the Chair.

The Right Hon. Sir James Graham, Bart. was elected a Fellow of the Society.

A paper was read, entitled "Some Account of a New Volcano in the Mediterranean." By John Davy, M.D. F.R.S. Assistant Inspector of Army Hospitals.

The first intelligence of the breaking out of the volcano, which is the subject of the present paper, was brought to Malta, on the 16th of July last, by a merchant vessel. It was confirmed soon after by Captain Swinburne, of H.M.S. Rapid, who had succeeded in approaching very near the island. The crater of the volcano, which was in great activity, was then only a few feet above the level of the sea. Several shocks of an earthquake had been felt near the same spot about a month before the eruption. The volcano continued active till the 16th of August, and the island it was forming gradually enlarged in all its dimensions; but since that period there has been no fresh eruption. In the end of August, a survey of the island was carefully made by Captain Wodehouse, R.N. of H.M. brig Ferret; and a plan drawn by him is annexed to the present paper. The circumference of the island is about 3240 feet, and its greatest height 107 feet; the circumference of its crater is about 780 feet. The surface of the island is composed entirely of ashes and cinders, without any lava. The crater contained turbid salt water, having a temperature of 200° Fahr. and emitting a constant supply of gas. The water in the immediate neighbourhood of the island was very shallow, not exceeding three or four feet, and the crater was rapidly filling up by the falling in of its margin.

The author could not learn that anything unusual had been noticed as having occurred in any of the neighbouring volcanic regions, either at the time of the eruption or immediately antecedent to it. He describes the phænomena, which fell under his own observation, on a visit which he made to the island on the 5th of August. During the most violent eruptions, a large quantity of dense white vapour, resembling snow or bleached wool, rose to a great height in the atmosphere, and assumed various extraordinary forms; this was followed by columns of perfectly black matter, rising to the height of three or four thousand feet, and spreading out very widely, even to windward. The subterranean sounds attending the eruptions were not very loud, and were much exceeded by that of the electrical explosions accompanying the lightning, which was seen to dart in various directions in the atmosphere of the eruption. To leeward of the volcano, the sea was much discoloured by the admixture of ashes and fine dust, and an abundance of light cinders were floating on its surface. Even when the author was enveloped in the dark cloud of ashes falling from the volcano, not the smallest odour of bitumen, of sulphuretted hydrogen, or of sulphureous or any other acid, was perceptible; nor was any inconvenience felt in respiration. No appearance of flame, and but little light, was exhibited during these eruptions.

The solid products ejected from the volcano appeared, on examination, to differ more in form than in chemical composition; and were found to consist of alumina, lime, magnesia, and silex, coloured by protoxide of iron, and without any potash. With the exception of small masses of vesicular basalt, similar to the common lava of Etna and Vesuvius, these materials exhibited no crystalline structure. The water taken from the crater appeared to consist of sea-water holding in suspension a fine dust, together with filaments resembling vegetable fibres, which the author supposes to have been derived from sea-weed drawn into the water. The saline ingredients of this water differed from that of the Mediterranean, chiefly in containing more sulphate of lime, and a little alumina, oxide of iron, and a trace of oxide of manganese; all these in combination with an acid, probably the sulphuric or muriatic, and a notable portion of hypersulphite of lime and magnesia. He could not detect in it any free acid or alkali, or the presence, even in combination, of any potash or ammonia, or nitric acid, nor the slightest trace of bromine or iodine. The gas emitted by the volcano appeared, as far as could be determined from an examination of two specimens, to consist chiefly of carbonic acid, with a trace of sulphuretted hydrogen.

The author observes in conclusion, that the results of his inquiry are almost entirely of a negative kind; and in this respect correspond with those obtained by Sir Humphry Davy, with respect to Vesuvius, and which are described in his paper "On the Phænomena of Volcanos," published in the Philosophical Transactions for 1828. They accordingly tend to corroborate the simple hypothesis there adopted in explanation of the phænomena of volcanic action; namely, that of the existence of an ignited nucleus of fluid matter, occasionally forced through the cooled crust of the earth by the expansive power of steam and gas: and they militate strongly against the hypothesis of the chemical origin of volcanos, and of their being attended by a decomposition of water by the metallic bases of the earths and alkalies.

A drawing of the volcano in its active state of eruption accompanied the paper, together with a plan and views of the island.

January 12, 1832.

JOHN BOSTOCK, M.D., Vice-President, in the Chair.

The Bakerian Lecture for 1832, entitled "Experimental Researches in Electricity—Second Series," by Michael Faraday, Esq. F.R.S., was read.

The success of the author in exhibiting the evolution of electricity by induction from ordinary magnets, led him to conclude that similar effects might be obtained from the magnetism of the earth, and even to an extent that might render it available in the construction of new electrical machines. These expectations have been fully realized; and the researches which establish the influence of terrestrial induction in giving rise to electrical currents, form the subject of this second paper.

Whenever a hollow helix, the terminal wires of which were connected with those of a galvanometer, and which inclosed a cylinder of soft iron, was held with its axis in the line of the magnetic dip, and suddenly inverted, the evolution of electric currents was immediately rendered sensible by the deflection of the needle of the galvanometer; a deflection in the contrary direction being produced the moment the helix was again inverted, so as to recover its first position. The same effect resulted from the simple introduction of the iron cylinder into, or its removal out of, the helix; evidently in consequence of the magnetism acquired by position with relation to the magnetic poles of the earth. When a cylindric magnet was substituted for the soft iron, the same phænomena, obviously ascribable to terrestrial induction, were in either case observed. Similar but more feeble indications of the same effect were obtained by inverting the helix alone, without its association with any ferruginous body whatever.

The influence of terrestrial magnetism in eliciting electricity from revolving metallic bodies was next made the subject of investigation. A copper plate was made to rotate in a horizontal plane, one of the wires of the galvanometer being brought into contact with its axis, and the other attached to a leaden conductor pressing against the amalgamated edge of the plate. The needle of the galvanometer was immediately deflected, either to the east or west, according to the direction of the rotation; and by successively changing this direction, and accommodating it to the oscillations of the needle, the arc of its vibrations was soon made to extend to 50° or 60°. When the plane of rotation passed through the line of dip, the galvanometer was not affected. A copper plate, revolving in a plane perpendicular to the line of dip, thus composes a new electrical machine, differing from the common plate machine in the circumstance of the material of which it is formed being the most perfect conductor, while in the latter it is the most perfect non-conductor. Insulation, which is essentially required in the latter, is fatal to the efficacy of the former. The quantity of electricity produced by the metallic machine does not appear to be inferior to that evolved by the glass machine, although differing much in its intensity. On employing copper wires of greater thickness, more powerful effects were obtained. The author expects that the effects may be still further increased by certain combinations of superposed plates, alternately revolving in opposite directions.

The author proceeds to show by experiment the manner in which terrestrial magneto-electric induction produces phænomena similar to those observed by Messrs. Barlow and Christie when ferruginous bodies are in rapid rotation, and which have been ascribed to a change in the ordinary disposition of the magnetism of the ball. He found that the rotation of a copper ball on an axis either horizontal or otherwise inclined to the line of dip, gave rise to a circulation of electric currents in a plane perpendicular to that of revolution, and in exact conformity with the law already deduced by the author in the first part of this paper. This law is illustrated in a very simple manner by the following experiment.—A copper wire, eight feet long, had its two ends fastened, each respectively to the ends of the wires of the galvanometer, so as to form with them one uninterrupted circuit. Upon moving the copper wire to and fro over the galvanometer, whilst the lower part remained steady, the magnetic needle was immediately deflected, in a direction regulated by the relative position of the wire and the direction of its motion.

It is a further consequence of this law, that the rotation of the globe of the earth itself must tend to induce electric currents in its own mass, passing in each hemisphere from the equatorial to the polar regions; so that if one set of conductors could be applied at the equator, and another at the poles, negative electricity would be collected by the former, and positive electricity by the latter. The electricity of metalliferous veins in the mines of Cornwall (of which an account has been given by Mr. Fox, in a paper lately published in the Philosophical Transactions,) does not appear, however, to be referrible to magneto-electric induction. It may be a question whether the phænomena of the Aurora Borealis and Australis may not arise from the discharge of this induced electricity consequent on the earth's rotation.

As it appeared probable that there exists some natural difference in the intensity of these electric currents induced by magnetism in different conducting bodies, the author endeavoured to determine what effects might arise from this difference in the case of iron and copper. For this purpose he joined together the ends of wires of each of these metals, each 120 feet in length, extended in the direction of the magnetic meridian. The copper wire was then divided in the middle and examined by a delicate galvanometer, but no evidence of any electrical current was obtained. The same negative result attended trials with wires of these metals, twisted together, and passed between the poles of a powerful magnetic battery. Similar experiments tried with other metals, and also with a circuit composed of copper and sulphuric acid, afforded in like manner no indications of electric currents. Hence it appears that when metals or other conductors of different kinds are equally subjected to magneto-electric induction, they exhibit equal powers with respect to the currents induced in them.

By another experiment the author shows that these effects of magneto-electric induction are not owing to the motion of the magnet and conductor relatively to each other, but that they take place to an equal degree when the two are united so as to revolve together, and when, consequently, they are relatively at rest. Electric currents are produced also in the substance of the magnet itself, simply by revolution on its own axis while floating on mercury, and the circuit completed by wires making a communication between the mercury and the axis of the magnet.

The author has comprised the phænomena here related in the following general formula. Referring to the pole of the magnet as the centre of action, if all the parts of the metallic conductor move in the same direction and with the same angular velocity, no electric currents are produced: but if one part cut the magnetic curves while another part is stationary, or if the motion of the whole be in one direction, but its angular velocity relatively to the pole of the magnet be different, then, in either case, currents will be produced; the maximum effect taking place when different parts move in different directions across the magnetic curves.

January 19, 1832.

JOHN BOSTOCK, M.D., Vice-President, in the Chair.

A paper was read, entitled "On the theory of the Perturbations of the Planets." By James Ivory, Esq. A.M. F.R S., Instit. Reg. Sc. Paris., & Reg. Sc. Götting., Corresp.

The methods hitherto employed by mathematicians for determining the variations which the elements of the orbit of a planet undergo in consequence of perturbation, and for expressing these variations analytically in the manner best adapted for computation, are found to depend upon a theory in mechanics, of considerable intricacy, known by the name of the *Variation of the Arbitrary Constants*. In seeking the means for abridging the severe labour of the calculations, we must separate the general principles on which they are founded from the analytical processes by which they are carried into effect; and in some important problems great advantage is obtained by adapting the investigation to the particular circumstance of the case, and attending solely to the principles of the method in deducing the solution. The author suggests the possibility of simplifying physical astronomy by calling in the aid of only the usual principles of Dynamics, and by setting aside every formula or equation not absolutely necessary for arriving at the final results.

The present paper contains a complete determination of the variable elements of the elliptic orbit of a disturbed planet, deduced from three differential equations, that follow readily from the mechanical conditions of the problem. In applying these equations the author observes, the procedure is the same whether a planet is urged by the sole action of the constant force of the sun, or is besides disturbed by the attraction of other bodies revolving round the luminary; the only difference being that, in the first case, the elements of the orbit are all constant, whereas in the other case they are all variable. The success of the method followed by the author is derived from a new differential equation between the time and the area described by the planet in its momentary plane, which greatly shortens the investigation by rendering it unnecessary to consider the projection of the orbit. But the solution given in the present paper, although it makes no reference to the analytical formulæ of the theory of the *Variations of the Arbitrary Constants*, is no less an application of that method and an example of its utility, and of the necessity of employing it in very complicated problems.

January 26, 1832.

JOHN WILLIAM LUBBOCK, Esq. M.A., V.P. and Treasurer, in the Chair.

The reading of a paper, entitled "Experimental Researches in Voltaic Electricity," by the Rev. William Ritchie, LL.D. F.R.S. Professor of Natural and Experimental Philosophy in the Royal Institution of Great Britain, and in the University of London, was commenced.

February 2, 1832.

WILLIAM GEORGE MATON, M.D, Vice-President, in the Chair.

Charles Octavius Morgan, Esq., Joseph Jackson Lister, Esq., William Gravatt, Esq., the Hon. William Francis Spencer Ponsonby, Captain Sir Samuel John Brooke Pechell, R.N., Frederick Madden, Esq., John Edward Gray, Esq., and Alexander Barry, Esq., were elected Fellows of the Society.

The reading of the Rev. Dr. Ritchie's paper, entitled "Experimental Researches in Voltaic Electricity," was concluded.

The author adduces many facts in refutation of the theory by which Volta endeavoured to explain the development of electricity in galvanic circles. He shows that the contact of dissimilar metals is not necessary for producing that effect, for galvanic action may be obtained by employing only one metal, if the two ends of the same copper wire be coiled into helices of different diameters, and immersed into dilute nitric acid. The experiments of Mr. Parrot of St. Petersburgh are cited as leading to results totally different to those on which Volta rested the foundations of this theory. The author points out several important marks of distinction between voltaic and common electricity, and denies that the latter is capable of passing into the former. He shows by an experiment that the free electricity developed by heat is independent of that developed by galvanic action. Chemical decompositions are effected in a totally different manner by voltaic and by ordinary electricity; for in the former case the two elements of the decomposed substance are found disengaged at the opposite poles, but in the latter they are developed at the same point, and appear more as the effect of a cleavage of the molecules by the mechanical agency of electricity. The author conceives that in a galvanic circle of zinc and copper with interposed water, the superior attraction of the zinc for oxygen produces an arrangement of the molecules of the water such that the particles of oxygen entering into the composition of each are all turned towards the zinc. This definite arrangement produces in its turn, by production on the neutral electric fluid contained in the metal, a corresponding definite arrangement of the two electricities along the whole electric circuit. Hence electro-magnetic effects may be obtained without any chemical decomposition; this latter effect taking place only when the attraction of the metal for one of the elements of the fluid is greater than that between the two elements of the fluid: and upon this principle the author conceives that the phænomena of the secondary piles of Ritter, and those observed by M. de la Rive, may be explained. By adopting the theory of the successive decomposition and recomposition of each particle of fluid in the line of action, we avoid the necessity of supposing the transference of the disengaged element through the intervening mass of fluid. Whatever circumstance favours the decomposition of the water, will also increase the power of the voltaic arrangement. Conformably to these views we find that all liquids whose component parts go to the same pole are non-conductors of voltaic electricity. A given section of a liquid is capable of conducting only a limited quantity of electric influence. It was also found by experiment that when sulphuric acid was employed, the quantity of electro-magnetic action in the connecting wire is exactly proportional to the quantity of water decomposed in the liquid part of the circuit. This quantity is, within certain limits, inversely proportional to the square root of the distance between the plates.

In the second part of this paper the author enters upon an investigation of the fundamental principle and laws of action of the voltaic battery. He calls in question the truth of the common theories of galvanism, which are founded on the supposition of electricity being accumulated in the poles of the battery before the circuit is completed, and of its actual transfer and continued circulation through the entire course of the circuit. In order to analyse the effect of a single galvanic circle, the author made the following experiments. A compound plate of zinc and copper soldered together was cemented into a trough, and two single plates of copper of the same size were cemented, one on each side of the former plate, into the same trough, so as to form a cell on each side of it; and the cells were filled with dilute acid. On connecting the extreme copper plates by metallic wires with a delicate torsion galvanometer, a certain deflection of the needle was produced. When two compound plates were placed between the terminal copper plates, the deflection was twice as great; when three were employed, it was three times as great, and so on. It is thence inferred that the voltaic effects of two batteries of the same length, and with plates of the same size, are directly proportional to the number of plates. By prosecuting this inquiry, the author finds that, within certain limits, the voltaic energies of two batteries, consisting of plates of the same size, and placed at equal distances, but differing in number, are very nearly proportional to the square root of the number of plates. This result was deduced both from the quantity of water decomposed by the apparatus, estimated by the quantity of hydrogen disengaged, and also by the electro-magnetic effects, as measured by the torsion galvanometer. But when the number of plates is greatly extended, the above law of increase is no longer observed, the effect being less than in proportion to the square root of the number. By continuing to increase the number of plates, we at length reach a limit beyond which there is no increase of effect, but rather a diminution. So that if the voltaic power were represented by the ordinates of a curve of which the abscissa denoted the number of plates, the curve, from being at first a parabola, would afterwards deviate into a form approaching to that of an ellipse.

In the third part of the paper the author relates experiments which prove that every part of the galvanic circuit conducts the same quantity of electricity, whatever be the material, whether solid or fluid, composing it; for the magnetic needle is deflected in an equal degree by every part. He succeeded in exhibiting the rotation of a piece of charcoal, and of a column of water, while transmitting voltaic electricity, round the pole of a magnet. Having noticed a difference of temperature in the fluid conductor in the vicinity of the two poles, he was led to investigate the cause of this phænomenon. A rectangular box being divided into three compartments by two partitions of bladder, and filled with water, and the wires from the two poles of the battery being inserted into the extreme compartment, the temperature of the water surrounding the positive pole was found to be higher than that surrounding the negative pole, and that in the middle compartment highest of all. These differences he ascribes to the cooling effects of the disengagements of the several gases at each respective pole, the volume of the hydrogen being double that of the oxygen, producing twice the effect. With metallic solutions, the reverse takes place, the effect depending in every case upon the relative specific heat of the substances disengaged at the two poles.

The reading of a paper, entitled, "On the Organs of the Human Voice," by Sir Charles Bell, Knt. K.H., F.R.S., was commenced.

February 9, 1832.

HIS ROYAL HIGHNESS THE DUKE OF SUSSEX, K.G., President, in the Chair.

A paper was read, entitled, "Some remarks on an Error respecting the Site and Origin of Graham's Island." By Capt. W. H. Smyth, R.N. K.F.M. F.R.S.

The author rectifies an erroneous assertion, originating from the report of Captain Larmour, who in the year 1800, when commanding the Wassanaer, a troop-ship on the Egyptian expedition, thought he observed a shoal of four fathoms water with breakers, within a mile of the latitude and longitude of the new volcanic island. The author has determined, by his own observations, that no such reef exists in that spot, nor is the assigned place of this shoal near that of Graham's Island, which arose considerably to the eastward, from a depth of above a hundred fathoms below the surface of the water. A knoll, with only seven fathoms of water upon it, was discovered not far from the site of these reports. The Adventure bank extends from Sicily nearly to Pentellaria, where the water deepens at once from 76 fathoms to above 375 fathoms, at which no bottom was met with. But, even on the supposition that what Capt. Larmour imagined he saw was the result of a temporary subaqueous volcanic eruption, it could not have justified the assertion of there being breakers with four fathoms upon them; and still less does it afford any foundation for the hypothesis that Graham's Island was formed by the mere lifting up of such shoal.

A paper was also read, entitled, "Researches in Physical Astronomy." By J. W. Lubbock, Esq. M.A., V.P. and Treas. R.S.

For the solution of mechanical problems, two methods in general present themselves: the one furnished by the variation of parameters, or constants, which complete the integral obtained by the first approximation,—the other furnished by the integration of the differential equations by means of indeterminate coefficients, or some equivalent method. Each of these methods is applicable to the theory of the perturbations of the heavenly bodies, and they lead to expressions which are of course substantially identical, but which do not appear in the same shape except after certain transformations.

The object of the author in the present paper is to effect transformations, by which their identity is established, making use of the developments given in his former papers, published in the Philosophical Transactions. The identity of the results obtained by either methods affords a confirmation of the exactness of those expressions.

Sir Charles Bell's paper "On the Organs of the Human Voice" was then read in continuation.

February 16, 1832.

HIS ROYAL HIGHNESS THE DUKE OF SUSSEX, K.G.,
President, in the Chair.

The reading of Sir Charles Bell's paper "On the Organs of the Human Voice" was resumed and concluded.

The author complains that the actions of the organs of the voice have been negligently treated by physiologists, and that many of the offices of the structures subservient to that function have been overlooked; and expects that the study of them will lay a foundation for prosecuting the intricate anatomy of the nerves of the neck, which he proposes to himself as an ulterior object. The subjects to which he particularly directs his attention in the present paper, are the Muscularity of the Trachea, the Position of the Thyroid Gland, and the Action of the Pharynx, which he alleges to have been entirely omitted in previous systematic accounts of articulate language.

The trachea is strengthened by imperfect circles of cartilage, the ends of which are united at the back part of the tube by a transverse layer of muscular fibres,—a structure which is very distinctly seen in the horse. This transverse muscle is an antagonist to the elasticity of the cartilages, and the effect of its action during expiration is, by contracting the diameter of the tube, to favour the propulsion of the mucous secretion, which may have been accumulated in the passage, and to contribute effectually to expel it by the effort of coughing. The same action leads also to the expulsion of foreign bodies which may have accidentally got into the trachea. In birds, where the inner surface of the passage is without moisture, no such provision was required; and accordingly we find the cartilages of the trachea are complete circles, not admitting of contraction.

The author considers the thyroid gland as serving the purpose of interrupting the vibrations of the cartilages of the trachea, to which it is closely attached, especially when pressed against it by the actions of the flat muscles which extend over it. If sound were given out by the vibrations of the trachea, it would interfere with the distinctness of the voice. The thyroid gland is, therefore, placed low in the larynx, and on the upper part of the trachea, for the purpose of checking the vibrations of that tube, and suppressing the sounds that would thence be produced. In birds, where the voice originates in the inferior larynx, and is propagated along the trachea, the structure of that tube is adapted to vibration, the circles of cartilage being complete, and there is no thyroid gland.

In man, the primary source of the voice is the vibration of the chordæ vocales, or ligaments of the glottis, acted upon by the impulsion of the air passing by them. The proper degree of tension is given by these ligaments by the action of the muscles, which adjust their position with the greatest accuracy. The movements of the chest, which regulate the expulsion of the air, are at the same time adapted with great nicety to the production of the required effect. The sacculi laryngis also contribute to give greater extent and freedom to the vibrations of the glottis. It is by the concurrent action of these organs that the breath, which under ordinary circumstances of respiration is inaudible, becomes *vocalized*, or thrown into sonorous undulations.

The author then gives an anatomical description of the pharynx and mouth, which together constitute an irregular cavity, extending from the glottis to the lips and nostrils, and of which the various changes of dimension and of form effect corresponding changes in the undulations into which the air is originally thrown by the vibrations of the glottis, and produce the different modifications of the voice. The most important are those which constitute articulate sounds. The simple vocal tones, or vowels, are greatly modified by the mere elongation or shortening of this cavity. But even in the formation of these, the contraction and appulse of the pharynx acts an important part; and in the articulation of the consonants it is a principal agent; its smaller cavity being, upon a well-known hydrostatic principle, substituted with great economy of power for the more capacious cavity of the chest. In pronouncing the explosive consonants, such as B, D, and G, the velum pendulum is raised, and, acting as a valve, closes the posterior nares; and the mouth being also closed, the vocalized breath, which continues to ascend through the glottis, suffers condensation, and gives rise to the faint sound which precedes the explosion consequent upon the opening of the closed cavity. This opening takes place, either by the separation of the lips, or by the removal of the tongue from the teeth, or palate, to which it had been applied. These previous actions of the pharynx and glottis are the circumstances which distinguish the sound of these letters from their corresponding mute consonants, P, T, and K. Thus the consonants, classed according to their formation in the mouth, either by the closed lips, the meeting of the lips and teeth, or the meeting of the tongue and palate, admit of varieties dependent on the actions of the pharynx and velum palati. The emphasis and accent given to particular syllables arise from two sources: namely, the variation in the action of the chest, and in the action of the pharynx.

This minute accommodation of action evinces not merely the perfection of the organ, but also its great subordination to the will; and in this respect the muscular apparatus of the throat admits of comparison with the delicate adjustments in the eye. Stammering arises, not from the defect in any single part, but from imperfect power of combining the requisite actions.

The author concludes by enumerating the variety of actions which must be combined before a word is uttered: namely, the compression of the thorax, the adjustment of the glottis, the elevation or depression of the larynx, and the contraction of the pharynx. He also adduces proofs of the correctness of the opinions advanced in this paper, drawn from the effects of accident and of disease occurring under his own observation; and from which he draws the following conclusions:—That the trachea gives out no sound of itself; that when the area of the passage is much diminished, the column of air has not sufficient force to move the chordæ vocales; that whatever interferes directly with the motion of the glottis reduces the voice to a whisper; that any permanent opening or defect of the velum, which prevents the distention of the pharynx and the closing of the posterior nares, renders articulation defective; that the obstruction or removal of the cells of the face deprives the voice of its body and clearness; and that nervous relaxation of the muscles of the throat is productive of great alteration in the voice. Hence the author infers the necessity of the numerous nerves which are distributed to these organs.

February 23, 1832.

HIS ROYAL HIGHNESS THE DUKE OF SUSSEX, K.G.,
President, in the Chair.

The reading of a paper, entitled, "On the Inverse Ratio which subsists between Respiration and Irritability in the Animal Kingdom; and on Hybernation," by Marshall Hall, M.D. F.R.S.E., communicated by J. G. Children, Esq. Sec. R.S., was commenced.

March 1, 1832.

HIS ROYAL HIGHNESS THE DUKE OF SUSSEX, K.G.,
President, in the Chair.

Dr. Hall's paper was resumed, and read in continuation.

March 8, 1832.

WILLIAM GEORGE MATON, M.D., Vice-President,
in the Chair.

The reading of Dr. Marshall Hall's paper, entitled, "On the Inverse Ratio which subsists between Respiration and Irritability in the Animal Kingdom; and on Hybernation," was concluded.

The object of the author, in the investigation which he has undertaken, and of which some of the results are given in the present paper, is to establish a law of the animal economy, which he expresses in the following terms: "The quantity of the respiration is inversely as the degree of the irritability." Other authors, such as Cuvier, attaching a different meaning to the term *irritability*, have stated this property, in the different classes of animals, as being directly proportional to the energy of the respiratory functions; the purposes of which they have considered to be those of restoring to the exhausted muscular fibre its contractile power. The author of the present paper regards animal life as consisting in two essential ingredients; namely, stimulus and irritability; atmospheric air being the principal source of the former; the heart, where it exists, being the principal organ of the latter; and the blood being the medium by which these are brought into contact.

For the purpose of ascertaining the quantity of respiration in any given animal, the author contrived an apparatus, to which he gives the name of the '*Pneumatometer*'. It consists of a glass jar inverted over mercury, and over the mouth of a bent tube, by which it communicates with a water-gauge of one tenth the capacity of the jar. Annexed to this apparatus, but unconnected with it, is a glass ball, containing ten cubic inches, and terminating in a tube, bent at its upper part, and of the capacity of one cubic inch, and inserted into a wider tube containing water, so as to correspond in all its pneumatic conditions with the jar and its gauge, and to point out whatever changes may have taken place in the volume of the air examined in the course of the experiment, from circumstances extraneous to it, such as variations of temperature, or of barometrical pressure. The animal, whose respiration is to be examined, is placed on a stand and covered with a jar; and the carbonic acid produced is absorbed by pieces of calico moistened with a strong solution of caustic potass, fixed by a wire frame in the upper part of the jar. The animal, at the end of the experiment, is withdrawn under mercury, without displacing the jar; the space it had occupied is filled with an equal volume of atmospheric air admitted into the jar; and the volume of oxygen gas absorbed is estimated by the column of water which has risen in the gauge.

From the facts detailed by Harvey, Goodwyn and others, which establish that in asphyxia the left ventricle of the heart ceases to contract before the right ventricle, the author infers that the irritability of the latter is greater than that of the former; and proposes to distinguish the first as *arterio-contractile*, and the latter as *veno-*

contractile, from the circumstance of their being stimulated respectively by arterial and by venous blood. He considers the power of bearing suspended respiration as a *measure* of irritability, which may be expressed by the length of time during which an animal can support the suspension of this function. He then shows that, conformably to these definitions, the fœtus before birth, the reptile, and the molluscous animal possess a much higher degree of irritability than the adult, or than animals belonging to the class of mammalia and birds; in which the quantity of respiration being very great, the irritability is proportionally small.

He then proceeds to consider the phænomena of hybernation; and shows that they are very similar to those of the ordinary sleep of the same animals, but differ from those of the sleep of animals which do not hybernate. In the former case the respiration is nearly, if not wholly, suspended, and the temperature greatly reduced; but the circulation continues unimpaired. He notices differences also in the habits of different hybernating animals, some of which frequently awake from their slumber during the winter, while with others the lethargy is uninterrupted. The state of hybernation should, he thinks, be carefully distinguished from the torpor induced by excessive cold; the former being a conservative, the latter a destructive process. The exclusion of atmospheric air, which is speedily fatal to the animal in its active state, is sustained with perfect impunity during hybernation, the respiration being then entirely suspended. The animal being at such times reduced to a state analogous to that of the reptile, but in a still higher degree, the irritability is much increased: the heart continues to beat without the stimulus of aerated blood, and the circulation is kept up with perfect regularity. This latter fact was ascertained by actual observation in the case of the bat, by adjusting the wing of the animal, so as to admit of its being placed in the field of a microscope without disturbing its repose. The experiments of Mangili are quoted in proof of the longer continuance of the action of the heart after decapitation, if the experiment be made in the hybernating state, than if it be made when the animal is in its ordinary state of activity.

Animals, during hybernation, are easily roused from their lethargy, and restored to sensibility and activity; and the muscles do not appear to be affected with the slightest rigidity: the respiration is immediately resumed, and the temperature rises rapidly to the natural standard. The hedgehog and the dormouse awake periodically from the sense of hunger, and the food then taken conduces to renewed lethargy. But frequent excitation from this state is productive of great exhaustion, and is often fatal to the animal. Severe cold, like other causes producing a painful impression, rouses the hybernating animal from its state of lethargy; and if continued, induces a state of torpor, which ends in death.